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OUTLINES OF THE FUTURE IN SPACE

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Translation of "Kontury budushchego," in "Stranitsy Sovetskoy Kosmonavtiki" [Pages of Soviet Cosmonautics], Moscow, "Mashinostroyeniye" Press, 1975, pp 313-348

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16. Abstract

Developments in the exploration of regions near the Earth, Moon, and the rest of the solar system, as well as practical applications of world space programs for the remainder of the twentieth century are discussed. A table of predicted dates of possible developments is given.

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OUTLINES OF THE FUTURE IN SPACE

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[Chapter 8 from the book "Stranitsy sovetskoy kosmonavtiki" [Pages of Soviet astronautics] by V. P. Denisov, V. I. Alimov, A. A. Zhurenko and V. A. Misharin, "Mashinostroyeniye" Press, 30,000 copies, 350 pages]

> [Text] "Man will not remain on the Earth forever; and in his pursuit of light and space, he will at first timidly penetrate the limits of the atmosphere and then conquer the entire solar system." K. E. Tsiolkovskiy

INSTEAD OF A PROLOG

People are more and more interested in the future. It captures the imagination. People dream about it, discuss it, and predict it, using statistics of the past and new scientific prediction methods.

The exploration of space is one of the greatest achievements of mankind. The task of those engaged in space exploration--people from a broad range of professions--is a difficult one. Scientists, engineers, designers, astronauts, workmen, and testers all have the right to be called right-flank men in the astronautics army consisting of many thousands. Astronautics is a tremendous catalyst of modern science and technology, which in an unprecedentedly short time has become one of the most important key factors in contemporary world progress. It stimulates the development of electronics, engineering, materials sciences, computer technology, power engineering, and many other branches of science.

Mankind is trying to find answers in space to such fundamental questions as the structure and evolution of the universe, formation of the solar system, and the origin and development of life. The study of the universe is currently undergoing rapid development. From an age of hypotheses concerning the nature of the planets and structure of space based on observations from Earth, we have advanced to a comprehensive study of heavenly bodies and interplanetary space with the aid of rocket and space technology.

Artificial satellites and orbital stations makes it possible to make a better study of space near the Earth and of the Earth itself, by essentially transforming its environment into a gigantic scientific laboratory. We are already obtaining appreciable benefits from the use of spacecraft in the solution of a number of problems of the national economy.

Penetration into space is proceeding at an ever increasing pace, and, although the conquest of space is difficult, it is believed that outer space will be of service to mankind, and its investigation and development will bring them, in the words of K. E. Tsiolkovskiy, "mountains of bread and an abyss of power." The foundation of the development of future programs and plans in astronautics is scientific and technological prediction.

Without considering the rather complex problems of scientific and technological prediction, we shall limit our discussion to the basic trends in the development of astronautics in the near future.

We shall do this in a manner used in contemporary scientific and technological prediction; i.e., we shall consider the prediction "free from surprises," for in most cases it is essentially impossible to predetermine new scientific and technological discoveries which are not yet known to us. And at the same time, as we have already noted, the basic difficulties in the development of concrete programs in astronautics result from a conflict between limited available funds, scientific and technological resources, and a sharp growth in the number of problems and requirements concerning the development of individual trends, complexes, and systems. This is particularly true of astronautics, if one bears in mind that each year facilities are being used in the solution of new problems, including ones which had not even conceived of 5-7 years ago.

Experience in the development and building of facilities of rocket and space technology shows that at the present time no individual country has the capability of carrying out all the valuable or even the technically possible projects since this would require tremendous material expenditures and industrial efforts. From this also follow certain differences in the space programs of the most advanced countries, such as the USSR and USA, which, one may assume, will continue to exist in the future.

International cooperation, which will help to bring about a systematic development of space by all countries without exception in a mutually advantageous manner, is also coming to play a special role. This will permit a significant expansion of the exploration frontiers and a rational breakdown of expenditures for astronautics. Astronautics will cross national boundaries more and more frequently and will be one of the areas of scientific and technological cooperation in the cause of progress of all mankind.

It is also clear that the development of astronautics can be significantly retarded if national interests are directed not toward peace but toward military actions. However, the experience of recent years shows that the international situation will improve, and success in this area will depend on the active participation of all progressive forces of society.

Thus far, the development of world astronautics has successfully passed through many stages. Our science and space industry have enabled the Soviet Union to successfully solve most of the problems of these stages during the first years of the space age. Space missions conducted by the Soviet Union in the future will also be determined by the needs of science, the national economy, and society.

It is not without reason that it is rather ponderably written in the directives of the 24th CPSU Congress that "the new outstanding achievements of Soviet astronautics are convincing proof of our country's high level of scientific and technological development."

BASIC TRENDS IN THE DEVELOPMENT OF ASTRONAUTICS

The goals of the development of basic trends in astronautics should be connected with the general goals of the state. These goals have been formulated in the following manner for our country:

"To ensure...that scientific operations in space are carried out for the purpose of developing long-distance telephone and telegraph communication, television, weather forecasting and the study of natural resources, geographic research, and the solution of other national economic problems through the use of satellites and automatic and manned spacecraft as well as the continuation of basic scientific explorations of the Moon and the planets of the solar system."

Yes, there is much to be done in space near the Earth which will aid in the solution of practical problems. Many secrets are still held by the Moon, the planets of the solar system, and the endless expanse of deep space. Doubtless, still other countries see in the basic trends of astronautics economic development, scientific development, technological development, and the development of international cooperation.

Economic Development. Space technology is already being used in the solution of a number of economic problems and is economically competitive with traditional technological measures (for example, in the fields of communication, meteorology, etc.). In the future, this course can and should be significantly developed in order to, on the one hand, expand the range of application of space facilities, and on the other, to ensure a return from the use of space technology and thereby justify the expenditures for the development of its various trends, which are not yet profitable but are important. The main objectives in this regard are the use of space facilities for the transmission of mass information and the establishment of communication, investigation of natural resources, weather forecasting and control, navigational and geodesic research, etc.

Scientific Developments. In the mastery of space the direct exploration of various regions of space is very important. The present level of space technology and predictions for its development in future decades show that the main object of such scientific investigations using space facilities will apparently be our solar system. Most important here are the study of space near the Earth and Moon, as well as the planets Mercury, Venus, Mars, Jupiter, Saturn, and others.

Space technology is particularly important in the development of astronomy and astrophysics, making them essentially sciences of all wave lengths because of the possibility of transporting astronomical instruments beyond the Earth's atmosphere. Scientists of our country and other countries see in the development of extra-atmospheric astronomy one of the most important scientific objectives of space exploration. Biomedical experiments will doubtless continue during long-range flights in order to determine the effect of flight conditions on the human organism and its ability to function.

Results of research on the behavior and functioning of biological specimens in space are important. Today we are witnesses to the implementation of ideas for using the properties of space (vacuum, weightlessness, and significant temperature gradients) for conducting original experiments in the "earth-based" sciences of biology, materials sciences, engineering, and physics.

Prospects for the near future are even more impressive. Information concerning conditions and phenomena occurring in space is extremely necessary for science and the practical needs of man.

Technological Developments. In the present state of its development, space technology is a powerful means of solving various scientific and economic problems. The rocket and space industry in the leading countries of the USSR and USA is well developed, and there is every reason to believe that it will continue to develop and improve in the future, being a potential foundation for the solution of more and more complex future space problems. For this reason, in an ideal situation the independent development of technology should anticipate the "demand" connected with the solution of problems which are urgent today and by convention can be considered as an independent trend. The most important problem areas here are the development of launch vehicles, engines, manned and unmanned spacecraft, and control facilities: command-measuring complexes, launching facilities, scientific apparatus, etc. In this connection, the solution of such general problems as reliability, quality, and development of structures with optimum parameters, as well as questions of organization and control of developmental processes in industry is also important. The goal of ensuring progress in branches of technology which are directly or indirectly connected with the development of astronautics is one of the more important ones.

The Development of International Cooperation. It is difficult to imagine the comprehensive systematic exploration and development of space in the interests of science and the national economy without extensive international cooperation capable of ensuring an efficient division of labor and economic expenditures. In addition, international cooperation represents one of the means of bringing nations together and thereby furthers the cause of peace.

The basic trends and problems concerning the further development of world astronautics are presented in table 8.1.

BASIC AREAS OF FUTURE USE OF SPACECRAFT

It is clear that astronautics will not enable man to go beyond the solar system before the beginning of the next millenium. Therefore, three basic areas of spacecraft use stand out quite prominently:

space in the vicinity of the Earth,
the Moon and the space surrounding it,
outer space (within the solar system).

Table 8.1. Basic Trends in the Development of World Astronautics

Transmission of information, establishment of communication, navigation, geodesy, etc.	Economic development
Investigation of the Earth's natural resources and production processes in space	
Weather monitoring and forecasting, monitoring of environmental pollutior, etc.	
Study of the Earth and space near Earth	Scientific development
Investigation and development of Moon	
Exploration of planets of solar system	
Exploration of Sun and interplanetary space	
Biomedical experiments in space	
Astronomical investigations in space and search for extraterrestrial civilizations	
Production of boosters and various stages	Technological development
Production of automatic space equipment	
Production of manned spacecraft, base stations, and transport facilities	
Production of control facilities and systems: engines, signal systems, launchers, control complexes, etc.	
Development of related technological fields (power engineering, chemistry, electronics, etc.)	
Selection of optimum forms and cooperative programs	Development of international cooperation
Joint explorations, exchange of information.	

One can assume that during this period astronautics will link various branches of science and technology even more closely, thereby permitting a systematic exploration of outer space and heavenly bodies, including the Earth, through the use of various types of manned and unmanned spacecraft. But what can we expect from world astronautics in the next ten to twenty years? How will the nature of space flights develop? What will manned and unmanned spacecraft, which are already being designed today, look like during that period? What can we expect in the more distant future?

In this chapter we shall present the predictions of Soviet and foreign scientists concerning the development of space technology and areas of its application.

More than any other, the twentieth century has been fortunate in being given appellations. At first it was the age of electricity, then, the atomic age, age of chemistry and even the age of biology. But its most recent, and, apparently, most accurate appellation is the space age. For the first time, man is beginning to feel that he is no longer simply a Russian, Frenchman, or Englishman, but that in addition to this he is an Earthling--an inhabitant of a small inner planet in the system of an ordinary star located someplace on the periphery of the galaxy, which itself is only an insignificant part of the metagalaxy, which forms a part of the infinite universe....

Mankind has started out on a path leading to unexplored spacial expanses.

But how far should we go along this path? And of what use is outer space to mankind? There are many questions and problems. We shall attempt to answer at least some of them. In order to do this, we shall make predictions for the near future and try to give an "eyewitness account" of the world in the last decade of our century.

* * *

By that time the world's population will have increased by 40 percent in comparison to the early seventies; it will be 4.3 billion.

In order to increase the supply of food, massive automation will have been introduced in agriculture, and an inexpensive method will have been found to desalt sea water.

In medicine transplants of natural organs will be common, and plastic and electronic organs will also be in use.

New effective medicines will have been created. The average life span will have increased significantly. Complex teaching machines will be in use.

Automated libraries, which locate and reproduce necessary material automatically, will be of significant help to researchers.

A worldwide communications system will have been created. Machines for automatic translation will be widely used. Automation will have extended its area of application from the performance of many auxiliary operations to the making of certain types of decisions. Significant progress will have been made in chemistry, mechanical engineering, power engineering, etc. Ion and nuclear engines will be in use. Reliable equipment with a service life of dozens of years will have been produced. The reliability and efficiency of this equipment and its systems will have been increased significantly.

High-capacity high-speed miniature computers will have come into general use. Important results will have been achieved in physics, mathematics, the natural sciences, etc.

A number of new discoveries and inventions will have been made in the fields of science and technology.

Man's knowledge of himself and his environment will have improved. This is the general picture. But what will astronautics be like and what role will it play? Let us briefly consider the three areas of use of spacecraft mentioned above.

SPACE IN THE VICINITY OF THE EARTH

What will the developments in this area of astronautics be like in the near future?

In answering this question, Academician B. N. Petrov, chairman of the Council on International Cooperation in the Exploration and Use of Space, "Interkosmos," wrote the following in his article "Zaglyadyvaya v budushcheye" [Looking Into the Future]: "The main objectives of the study of space near the Earth will continue to be the further investigation of the Earth's upper atmosphere, magnetosphere, Sun-Earth communication, cosmic rays, extragalactic sources of radiation, and other problems of interest to present-day science. Practical aspects of the application of space technology will play an ever increasing role. Space communication and television will begin to develop rapidly.... In time, even a worldwide system of space meteorology with effective means of processing information and extensive use of computer technology will appear....In the more distant future, at least partial control of the weather will doubtless become a reality....Navigation satellites will give important practical results...." Systematic scientific investigations and experiments dealing with the national economy using manned and unmanned spacecraft will continue in this area of astronautics, which will continue to be of primary importance. It is here that various systems of unmanned spacecraft for the national economy will have been developed. It is here that permanent manned orbiting space stations have been assembled and operate, and here from an intermediate orbit preparations are being made to launch missions to Mars, Venus, and the other planets.

Artificial satellites have become more specialized, and this has permitted deeper studies of various phenomena and processes which take place in space and on Earth. Temperature-control, telemetry, and radio-equipment systems, among others, have become standardized and are used in devices for various purposes. Their service life is measured in tens of years. When necessary, new specialized systems are created from automatic spacecraft. The cost of various spacecraft and launch vehicles has been made several times lower because of the transition to new principles of development and use of technology and production. Results obtained through the resources of space technology find extensive application in science and the national economy. Progress in the area of launch vehicles has resulted in the production of reuseable launch vehicles, and their increased power-to-weight ratio permits launching of a significantly larger payload than during the first 18 years of the space age with a lower relative launch cost.

Engineers and technicians will also have multi-purpose heavy automatic satellites with various equipment for making systematic observations.

The fruits of space exploration are quite tangible, both economically and in their practical application. Storm warnings and accurate weather forecasts for a month or more in advance make it possible to determine the right time for agricultural, construction, and other types of work. Detailed forecasts significantly improve the safety and cost factor of shipping. Television and infrared equipment regularly survey the Earth's cloud cover. Information is transmitted to clients.

Actinometric equipment permits a "heat" survey of the Earth, i.e., determines the intensity of heat radiation currents in various regions of the Earth's surface and atmosphere. The Earth's atmosphere is studied systematically and deeply. Widely used is the so-called vertical sounding from satellites equipped with infrared spectrometers and other sensitive instruments using the principles of photography, thermal display, radar, laser display, etc. Transmitted information includes not only information concerning stratus and cumulus clouds, cyclones and anticyclones, ocean storms and snow and ice conditions, but also information from the satellites concerning changes in the water level of rivers, amounts of precipitation that have fallen in different areas, temperature profiles at all altitudes beginning with the Earth's surface and extending to the upper layers of the atmosphere, and many other things.

Scientists have placed new investigations and experiments on local variations in meteorological conditions on the agenda. They are attempting to reduce the harmful effects of hurricanes, disperse fog and hail, and regulate the duration and amount of precipitation, and are making preparations to make climatic changes on a worldwide scale.

In this period satellite communication systems are undergoing an explosive development. A new type of satellite has been developed whose transmitters have a high output power, as a result of which telesignals are transmitted to individual television sets directly, by-passing points on Earth for the reception of messages (the "Orbit" type of the seventies) and a network on Earth for relaying them from one region to another.

Communications satellites will mainly be placed in stationary orbits. Such satellites revolve around the Earth in one day, the height of their circular orbit is about 36,000 kilometers, and the plane of their orbit coincides with the equator. A Satellite of this kind seems to be "suspended" over a particular point on the Earth's surface since the angular velocities of the satellite and Earth are the same at this point. Only three or four stationary satellites are needed for global communication.

Human communication and association have become universal with the aid of space technology and special simultaneous translation systems.

Satellites have also played an important role in the development of navigation. They have become the main element in the international navigational system. And in order to accomplish this, only a few satellites were needed. The navigational system in space in conjunction with a land-based guidance system and airborne equipment on airplanes and spacecraft make it possible to locate objects at any time of day and in any kind of weather with a high degree of accuracy. Comparatively large errors in navigational measurements have become a thing of the past; accuracy has increased by one order of magnitude or more. This is essential, for the number of sea-going vessels and aircraft is rapidly increasing, and safety of movement on the crowded routes is becoming difficult. It becomes necessary to lengthen voyages and change routes, which leads to unnecessary expenses and increased travel time.

One of the valuable features of navigational satellites is the possibility of organizing rescue services for air and water travel.

Important practical problems are also solved with the aid of geodetic satellites.

In order to determine the coordinates of a given object, geodetic satellites use reference points with coordinates that are precisely known at a given moment. In the process, simultaneous measurements are made of the satellite's coordinates from several points on the Earth's surface, and then the location of the point in question is determined by performing relatively simple computations. Thus, satellites permit spacial triangulation of a sort.

Use of geodetic satellites makes it possible to determine more exactly the coordinates of geographical points and also to determine with a high degree of accuracy the position of any point on the Earth's surface relative to the center of mass of our planet. These satellites have also come to be used to investigate changes in coast lines, to align tracking stations with manned spacecraft, and to solve many other problems. The satellites have proved very effective in such fields as oceanography, hydrology, geology, agriculture, etc. Equipped with various apparatus and instruments, these satellites have found broad application in a very short time and have aided man in the observation of glaciation of polar waters, the study of ocean currents, coastal geology, and marine life. They have made it possible to study the geological structures of continents, draw more accurate geological maps of the Earth, study land resources, increase cultivated land area, improve harvest planning, and much more.

Artificial Earth satellites can render invaluable aid in the preservation of the Earth's forest areas. Forest fires, which destroy millions of cubic meters of timber yearly, have done tremendous damage to the economy. The prevention and early detection of forest fires is of particular importance for our country, which has the largest forest areas. To this end, significant resources have been used, and hundreds of aircraft have made prolonged flights over the "green ocean" daily. The use of satellites to detect fires has greatly improved the effectiveness of fire control. The field of vision of optical equipment on board a satellite is hundreds of times greater than that of an airplane pilot. Because of their speed relative to the Earth's surface and their efficiency in dealing with incoming information, one or two satellites could actually sharply decrease the number of airplanes used in searching for fires.

Observed from space, variations in natural phenomena appear more clearly and more to scale. Let us consider the problem of soil erosion as an example. What proportion of dry land consists of eroded soils and in what stage of development are they? This can be determined from photographs taken from spacecraft. Using spacecraft, it is possible to solve a number of other problems as well. For example, it is possible to classify soils in various regions in order to determine how they can be best used or make a rational selection of distant pastures and places for cattle to be kept in winter. With sufficiently accurate equipment it is possible to determine the extent to which soil has been heated and effectively deal with plowing and planting, determine the extent of germination and maturation of crops, and efficiently manage harvesting operations. Under such conditions crop losses will be significantly curtailed.

Spacecraft will be used in prospecting for minerals. It has been discovered that certain minerals can be found only in specific rocks, which can be seen from high altitudes by their characteristic coloration and occurrence (for example, chromium, iron, and manganese ores, phosphorites, and others).

Various instruments on satellites for investigating natural resources have helped to record new oil fields and make a more thorough study of vegetation zones.

The more accurate determination of wood supplies and types in forests, tracking of wild animal migrations, monitoring of crop maturation time, prospecting for minerals according to the structure of geological formations, magnetic irregularities, and types of vegetation--all this is far from a complete list of the responsibilities of artificial Earth satellites.

Most types of unmanned spacecraft conduct scientific and technical experiments in accordance with coordinated programs of various countries within the framework of international cooperation.

Man is becoming more and more accustomed to space as a result of the use of manned and unmanned vehicles. People go to work in space, and workdays in space pass. The main goal in the area of manned flights is the creation of highly efficient orbiting space stations intended for long-term operation.

In 1971 Academician B. N. Petrov wrote the following: "...If the possibility of a human being flying into space and working there was demonstrated during the first decade, the second decade will be a period of systematic research work using orbiting space laboratories. Space technology will clearly follow a systematic path in the building of orbiting space stations; at first they will be simple, then bigger and bigger and more and more complex and designed for carrying out scientific and technical experiments in space..."*

It is quite understandable that the construction of permanent orbiting space stations equipped with a complex of scientific equipment and able to accomodate a large crew including scientists in various specialties was a very complex problem. Naturally, this problem could not be solved at once. Before people left for permanent work in space, it was necessary to determine, among other things, what the effect of prolonged weightlessness would be on man, whether it would be necessary to create an artificial gravitational force in the stations, and what its minimum value should be. What kind of space stations are these, and what are their structural properties? The process of their development is proceeding systematically and is characterized by increases in weight and crew size, as well as by a growth in the extent and complexity of problems being solved. For example, in the late seventies it was possible to use an orbiting space station, which was a magnificent structure consisting of two joined "Salyut" space stations serviced by transport vehicles. The crew of the space station consisted of six to eight people, and the volume of the work areas was more than 200 cubic meters. The mass of the equipment for conducting experiments was over 10 tons. The space station and mission service transport vehicles comprising this scientific complex in earth orbit have been improved and have a number of new systems. For example, there is a special module in which artificial gravity is maintained by imparting the necessary angular velocity to it. On board the space station there is also a special greenhouse where flowers and fruits are grown and where astronauts can spend hours of their leisure time in a green oasis, getting tanned by the rays from an artificial sun.

*B. Petrov, "The Exploration of Space: Successes, Trends, and Landmarks" in "Problemy mira i sotsializma" [Problems of Peace and Socialism], No 4, 1971.

There are also hatches and an airlock module for the crew to enter open space. The purpose of such walks by astronauts is to conduct external inspections of the space station and, when necessary, make minor repairs to external equipment and return to the space station results of experiments from instruments attached to special booms or flexible cables. A telescope and other complex equipment for making observations of heavenly bodies are located in the astronomy module.

In space the medium is perfectly transparent; this means that conditions for astronomical observations are most favorable. Investigations of the depths of the universe are carried out within the entire electromagnetic spectrum, from short gamma rays to long radiowaves. Generally speaking, astronomy is becoming more and more a space-based science rather than an earth-bound one. Because of the abundance of atmospheric interference, observations made from Earth to beyond the Sun are not very favorable either. Besides, unexpected intense solar flares, unusually shaped protuberances, and the diverse spectrum of charged particles emitted from the Sun are all very valuable material for geophysicists.

Study of radiation of all wavelengths has become accessible to the complex of scientific instruments on board an orbiting space station. A very wide range of objects is being studied on the space station: sources emitting gamma rays and x-rays, which is characteristic, for example, of neutron stars, as well as sources with an insignificant surface temperature, and dark dwarfs, which are abundant in our galaxy and, possibly, occur in the vicinity of the solar system.

The study of quasars and pulsars will help to solve the problem of the origin of the universe as a whole. Doubtless, materials obtained at a space observatory will make it possible to uncover many new secrets of the universe.

As a rule, astronomical instruments are custom-made and therefore expensive. They are intended for long-term use; the discovery of new principles in the realm of heavenly bodies requires prolonged systematic observations, often not only of one but of several similar specimens. Nevertheless, even the most perfect equipment requires preventive maintenance, adjustment, and technical servicing.

Manned orbiting astronomical observatories, the personnel of which is changed from time to time, constitutes the ideal solution to the problem of effective and efficient use of expensive equipment.

Physicists have acquired an excellent laboratory: the perfect vacuum of space and all the components for space research.

With the creation of the orbiting space station, geophysicists and physicists, after their study of the atmosphere, began to regularly conduct prolonged investigations on a broader scale as well.

Of interest is the performance on space stations of extensive biomedical research on humans, animals, and plants under conditions of prolonged stays in a space environment. All this is necessary for man to be able to make flights to other planets and to improve procedures for selecting and training astronauts. As was expected, weightlessness has proved beneficial in the treatment of certain diseases. Such factors as vacuum, the broad radiation spectrum, specific heat-transfer conditions, and weightlessness are all key factors affecting a living organism. It simply would not be acceptable for medicine in the new millenium not to learn to make use of them, especially to cure patients who are incurable under conditions on the Earth's surface.

These same factors of space flight came to be used in the development of a special space technology due to the fact that many physical and chemical processes proceed in a completely different manner in orbit than on the Earth's surface. This made it possible to conduct on orbiting space stations the first experiments to create chemical and biological substances, extremely effective medicines, and unusual structural materials with new properties that could not be produced on Earth.

Various instruments on orbiting space stations solve problems of the national economy. We have already discussed many of them in our treatment of satellites. We shall merely note that orbiting space stations, as is the case with meteorological satellites, make it possible to monitor weather conditions on a global scale, ensure the regular acquisition of scientific data about our planet and the space surrounding it. They have become first-rate laboratories for conducting scientific and biomedical experiments.

Nevertheless, it is perfectly clear that orbiting space stations have much more to offer for the further progress of mankind. The presence of man on board a space station or manned vehicle will increase the efficiency with which tasks are performed, thanks to the use of his reactions and ability to analyze information, draw conclusions, and make decisions in unexpected situations. Man's ability to select the right solution from among several possibilities permits simplification of certain elements of on-board equipment and their operating principles.

In the supervision of equipment, man's role consists in the "detection of malfunctions," i.e., by using a system of indicators, a person must detect and pinpoint the location of the malfunctioning element. A person usually combines a number of functions, performing them in succession or simultaneously. In case of some previously unforseen circumstance, he is capable of changing the control methods for systems.

An automatic machine has its own, rather important, virtues: it is not subject to fatigue, irratibility, uncertainty, fear, and other emotions. But only a human has free will, a mind, and creativity. The automatic machine will not force man from the sphere of creative activity. We are speaking only of an optimal combination of properties and qualities of man and machine in order to best solve a given problem.

Some spacecraft operating in space near the Earth continue to be purely automatic as before, while others are visited by astronauts, who check their operation, make adjustments, changes, or repairs to malfunctioning equipment, and collect information. As a rule, these are large complex automatic laboratories.

Having discussed the problems being solved using permanent orbiting space stations, we should mention that transport vehicles and orbiting space stations of other countries can rendezvous and dock with them. To this end, the development and standardization of procedures and systems for the mutual tracking of spacecraft of various countries and their maneuvering and docking in orbit began as early as 1972 in accordance with an agreement between the USSR and USA.

The structure of an orbiting space station to a large degree determines how it is assembled. The "Salyut" space stations were assembled on Earth and launched into orbit ready to begin performing their tasks immediately. In orbit only a docking principle was used, which was similar to the one used to assemble the first experimental orbiting space station by docking "Soyuz-4" and "Soyuz-5."

However, it is also possible to assemble a space station in orbit by using a special assembly and repair unit. To do this, the elements of the space station are launched into orbit using several launch vehicles. In this manner it is possible to build space stations of any mass, size, and appearance.

Scientists meticulously calculated which method would be better. Both have their advantages and disadvantages. Finally, they came to the conclusion that a composite method based on the assembly in space of subassemblies was required. The modules and hatches of the space station were completely assembled on Earth, launched to the assembly area on a cargo launch vehicle, and linked up automatically or by space assemblers. A space station assembled from such modules (or sections) can have any configuration: it can be cylindrical, spherical, dumbell-shaped, torus-shaped, have the shape of a hub with blades, etc. The torus-shaped space station is to be preferred, for it is very suitable for the creation of a constant artificial gravity. The modules are air-tight and are connected by roomy hatches. A number of modules are equipped with automatic life-support systems. Some of the modules are equipped with rendezvous and docking facilities for the docking of space vehicles. The space station has an entire cosmic "shipyard," where transport vehicles can be repaired when necessary.

The space station is designed to function for decades, and, therefore, new photographic equipment, multipurpose equipment, and a high-capacity nuclear electric power plant are planned for it.

Not far from the space station is a gigantic expeditionary vehicle for flights into deep space. A scheduled flight is getting ready for take off. Thus, manned orbiting space stations will become a unique intermediate or connecting link between the Earth and the other planets of the solar system. They will make it possible to solve many complex problems connected with the final preparation of vehicle systems and astronauts before flights to other planets, the lengths of which will apparently be measured in years.

The space station has everything needed for working and living for several years, but, nevertheless, regular contact with Earth by means of space shuttles is necessary. The shuttles regularly bring crew replacements to the space station, deliver components for the life-support systems, equipment, and instruments. These same vehicles return people to Earth from the space station, as well as cargoes and data from scientific experiments, which will be analyzed on Earth. In comparison with the spacecraft of the seventies, which traveled along an Earth-Earth orbit-Earth route, the external shape of the shuttle has changed considerably. It has wings designed for entry into the atmosphere at high speeds as well as good aerodynamic characteristics when soaring at low altitudes. To a certain extent, these vehicles have become similar to supersonic aircraft.

The main virtue of the space shuttle is the possibility for horizontal maneuvering during entry into the atmosphere (and in individual cases, on take off as well, if this should be necessary) as well as the possibility of repeated use, which significantly decreases the cost of equipping and servicing space stations since one and the same shuttle can be used dozens of times for flights into space, which lowers the cost of taking crews and cargoes to the space station and returning them to Earth. Naturally, flight frequency is also determined by the size of a space station crew, the duration of its stay in orbit, the necessity to replenish used-up materials, the delivery of new equipment, and, finally, the load-carrying capacity of the shuttle.

A single system consisting of an orbiting space station and space shuttles can be used for interplanetary communication. For example, for an astronaut to reach the Moon, it is necessary to perform the following operations: A shuttle capable of being launched from various places on Earth transports a person to the orbiting space station. He then transfers to a shuttle which travels along a route from an Earth orbiting space station to a Moon orbiting space station. Then there is another transfer, now to a Moon shuttle, which will transport the astronaut to any area on the Moon. Naturally, the two latter types of space shuttle craft differ in external appearance from the former in that they do not have wings (they are not needed in the vacuum of space!); for flight and control they use jet engines, which produce a reaction force.

What is the shuttle which travels between the Earth and the orbiting space station like? In order to put comparatively small payloads measured in hundreds of kilograms into orbit, it is possible to use a rocket glider, which takes off from Earth, goes into orbit, and then returns into the atmosphere with the aid of retrorocket engines, and lands at an airport like an airplane.

It is obvious from the point of view of power that it is advantageous to use multistage systems, as is the case with present-day launch vehicles. In this case, a rocket with reusable stages launches the rocket glider-space shuttle, which docks with the orbiting space station, and then makes a flight according to a previously worked-out plan. In connection with the necessity of further increasing the number of shipments being taken into orbit, the weight of transport systems will increase at the beginning of the new millenium, and, in this connection, it will be advantageous to divide shuttle craft into cargo, cargo-passenger, and passenger vehicles, as is the case with ordinary transport vehicles on Earth.

This is an outline of what the authors believe space exploration and experiments near the Earth will be like.

THE MOON AND THE SPACE AROUND IT

The Moon continues to be an unusual scientific and technical "proving ground" where a diversified program of scientific research is being conducted, and structures and systems are undergoing comprehensive testing to determine their fitness for use under conditions involving sharp temperature gradients, vacuum, and low gravity. Using stationary and nonstationary automatic devices operating on and near the Moon, new information has been obtained about the physical and chemical properties of the Moon, and our ideas concerning the origin and structure of the universe have been expanded. Necessary experience and practical data for producing new spacecraft for various applications have been accumulated.

What then are the basic prospects for the exploration of the Moon?

Use of unmanned synchronous and nonsynchronous spacecraft for studying the Moon has fundamentally expanded areas of possible investigation. Fundamental studies are being made of the far side of the Moon, polar zones, areas of the Moon with high mountains, and many other areas of interest to scientists. Science is in great need of observations of heavenly bodies made from space. They can be conducted not only from satellites in Earth orbit but from the Moon's surface as well. This makes it possible to study the radiation of stars and other objects in space within the entire range of their spectrum, which cannot be accomplished from Earth because the atmosphere admits far from all radiation. Studies of the Moon have been made from satellites in orbit around it and on its surface. Unmanned rovers render invaluable aid. With them the most extensive complex of diverse scientific and technical experiments is being conducted. In this connection, direct communication with Earth is not at all necessary. Moon rovers have long operated where radio contact with Earth was not possible and studied the far side of the Moon. In the process, messages are transmitted by means of artificial Moon satellites.

The agenda includes the question of transforming the entire network of satellites in orbit around the Earth and Moon into a single gigantic antenna system, which will make it possible to reliably control the movement of spacecraft in the future, not only in the solar system but beyond it as well. And mankind is certain that this will soon be the case, for astronautics is developing rapidly, systematically, and purposefully.

In the meantime, the scope of problems being solved by Moon rovers has broadened significantly, by analogy with the tasks of cars and jeeps used on Earth. They now travel in various lunar regions, in the form of small power-driven devices to accompany astronauts moving on foot, in the form of vehicles for transporting astronauts, or in the form of mobile laboratories, which automatically perform various operations and investigations. Experiments are being conducted on the use of Moon rovers in the construction of lunar bases. In a word, various mobile devices, in conjunction with present-day automation, have significantly increased the possibilities for man to explore not only the Moon, but other heavenly bodies as well.

An automated "Moon service" is being built on the Moon. These continuously operating technical facilities include satellites for lunar orbit, stationary unmanned lunar bases located in the scientifically most interesting regions, moon rovers, and a complex of unmanned spacecraft to provide the "Moon service" with necessary equipment and supplies and to transport a crew to service this lunar laboratory when necessary.

Automatic machines perform the basic work and long-term systematic investigations. Man monitors the results of the experiments and conducts only special complex investigations which are still difficult for the automatic machines. He also makes routine checks in the "Moon service" system, adds to the lunar base equipment transported from the Earth in preassembled units, and performs construction and assembly operations dealing with the building of a permanent manned science base.

Many new expectations are connected with man's activity on the Moon, including the building of industrial enterprises on its surface during the new millenium. It is also becoming clear that future development of the Moon will require new solutions in the areas of transportation and construction.

For example, in order to transport cargoes to the Moon, a "low-speed" transport vehicle with low-thrust ion-plasma jet engines will be used. The flight of such a vehicle on the Earth to Moon route will take from 1 to 3 months. Lunar cargo vehicles can be unmanned; they can be controlled automatically. Nevertheless, the basic transportation systems during the period of lunar development will have to be reusable since this is much more efficient and economically advantageous. Expendable systems can be used to transport large-sized structures, fuel tanks, and life-support components for the long-term operation of the lunar base, such as oxygen, water, fuel, etc.

A lunar orbiting space station will be built in lunar orbit in addition to the unmanned satellites of the "Moon service." Manned space vehicles will dock with it instead of landing on the Moon's surface.

Transportation between the space station and the Moon will be achieved using lighter vehicles. Such a system will give a fuel saving by eliminating the necessity of a heavy vehicle having to overcome the Moon's gravity during landing and take-off from its surface.

The lunar orbiting space station itself, by analogy with Earth space stations, will be a powerful scientific research complex for the comprehensive exploration of the Moon. It will constantly be added to and expanded through the addition of new modules necessary for scientific research, living quarters, the servicing of lunar vehicles and vehicles of the Earth orbit-Moon orbit system, repairs, etc.

In order to provide comfort in the living quarters and counter the effects of weightlessness, the space station, like its "sisters" in Earth orbit, will rotate on its axis and have a toroidal shape with a cylindrical work area.

In time lunar transport vehicles of the Earth orbit-Moon orbit system will also have high-thrust nuclear rocket engines, which will reduce flight time from 3-3.5 days to 10-12 hours.

Experience in the development of engines with a solid core will serve as the basis for the production of nuclear engines with a gas core, which are several times more powerful than engines with solid fuel elements. The agenda will include questions concerning the production of thermonuclear rocket engines and even photon engines with a gas laser and nuclear reactor. But a photon engine can be produced in final form only after the creation of a powerful energy source based on the annihilation of matter and antimatter.

Obviously, all legal aspects of the use of nuclear engines and other high-energy systems will be strictly observed by the countries that create such technologies; they will ensure safety of operation and prevention of pollution of space in the Earth's vicinity.

It is obvious that during the period of extensive development of the Moon, a space rescue service will also be established. Its vehicles will render aid to crews of transport vehicles which have become disabled in space, and in the event repair is necessary or advisable, damaged vehicles will be put in working order. If, however, repair proves to be inadvisable for some reason, the vehicle will be destroyed or transported to sparsely inhabited regions of space. For the same purpose a special network of communications and navigational systems will be developed consisting of Earth-based and orbiting devices of various kinds and provides manned spacecraft with accurate information for flights along given trajectories. This will significantly improve flight safety.

A base will be established on the Moon's surface and in its interior for the housing of a large number of specialists in the development and investigation of our natural satellite. Later, autonomous complexes will be built in the same location for the production of liquid hydrogen, oxygen, and other types of fuel, as well as the industrial exploitation of its natural resources, although it is unlikely that it will prove advantageous to transport these products of lunar industry to Earth. Apparently, they will be needed here, on the Moon, to supply the base and other settlements.

By the beginning of the new millenium the most unexpected fundamental discoveries may have been made. For this reason, our prediction is not utopian; on the contrary, it is more likely that it will prove to be ultraconservative. In any case, time will tell and corrections will be made. In the meantime, mankind is considering plans for the future development of the Moon, determining its benefits and analyzing expenses and investments, and quite a few will have to be made: for the creation of a permanent lunar base, for the construction of a space port on the Moon for manned expeditions to the distant planets, and, finally, for work on the use of the Moon's natural resources and the building of cities on the Moon. Yes, it is necessary to approach the development of the Moon carefully, weighing everything pro and con, and analyzing investments and the effect produced. Nevertheless, we believe that the time when cities will be constructed on the Moon is not far distant, for we already have more than a quarter century's experience in the investigation of the Moon with unmanned spacecraft and regular manned missions. And that is quite a lot!

IN ORBIT IN THE SOLAR SYSTEM

It is completely natural that many are now interested in the question: Of what practical benefit to people can the exploration and development of regions of deep space and of heavenly bodies, including the planets of the solar system closest to the Earth, be?

The present status of space exploration could be compared with that time in each person's life when, after appearing in this world, he suddenly begins to become aware of the surrounding world. Nothing is solid; everything is in motion. There is a constant flow of new information, and a constant expectation of even more amazing discoveries.

It would be appropriate to mention here two statements made by Academician M. V. Kel'dysh before scientists of our country during a discussion of goals for the Ninth Five-Year Plan.

He said in part: "The amazing discoveries of the past decade in astrophysics point to the possibility of the existence of new states of matter and are transforming our ideas about the universe. In addition, technical progress has enabled man to go beyond the boundaries of Earth into space, and this has opened up new tremendous possibilities for the solution of many practical problems on Earth, for penetration into the solar system and its exploration, and for the development of fundamentally new means of exploring the entire universe." He continued: "The discovery of such remarkable objects as pulsars and quasars and the detection of relict radiation, infrared radiation of galaxies, and x-ray sources have created an impulse for intensive investigations of the structure and evolution of the universe, galaxies, and stars and the discovery of processes which are possibly connected with new forms of existence and the laws of transformation of matter. It is necessary to support research in these directions in every way possible: They are of great scientific interest, and it is possible that in the future they will open fundamentally new possibilities for the use of the laws of nature."

It is perfectly obvious and understandable that the exploration of regions of interplanetary space far from the Earth with unmanned spacecraft is of fundamental importance to mankind. As for the exploration of planets of the solar system, the following circumstances may be decisive.

One of the reasons why our planet has not yet been adequately studied is that scientists cannot "compare" it with any other heavenly body. By studying a single example of a heavenly body, our planet, they are not in a position to distinguish the regular and general from the coincidintal and individual.

Allowing space technology the possibility of becoming familiar with the state and properties of other planets of the solar system, where many processes take place in other thermodynamic, physico-chemical, and other circumstances, will permit a deeper understanding of processes which have taken place on Earth in various stages of its evolution and a more exact evaluation of existing cosmogonic, cosmological, geophysical, biological, geological, and other ideas concerning the origin, development, and internal structure of the Earth. This, in particular, will contribute to a deeper understanding of the principles of the formation and distribution of the Earth's minerals and, consequently, to the improvement of geological predictions, which are of such importance for mankind; it will also help explain the Earth's internal structure. This is of great significance to us. After all, the causes of volcanic activity and earthquakes are still unclear. We also do not understand the causes of the formation of vast mountain ranges and gigantic faults, which are several kilometers deep and extend several thousand kilometers. The pressing need to study volcanic activity and earthquakes on heavenly bodies is quite obvious.

By investigating the nature of volcanic activity, earthquakes, and climate on other heavenly bodies, it will be possible to uncover their secrets on Earth as well.

The high level of development of rocket and space technology is opening up the possibility of interplanetary voyages in the future. However, in order to achieve this, many complex scientific and technological problems must still be solved. In the opinion of many medical scientists, one of these problems is that of safeguarding the lives of crew members on space vehicles.

For manned space flights to become a reality, it is first necessary to ensure that a manned vehicle is protected against radiation. No less important are the establishment of required temperature conditions, normal heat-exchange processes, and normal pressure in the space vehicle, as well as providing it with oxygen, water, and food that will keep for long periods. And, finally, it is necessary to make a thorough investigation of man's ability to withstand acceleration and prolonged weightlessness.

The solution of even one of these problems is a very difficult task, the complexity of which increases as flight duration increases. And how many other problems are there? Today manned space flights are made only near the Earth and Moon. In the future flights to the planets will also be possible.

Man's penetration into space is a natural step in world scientific and technological progress. Along with the development of our planet's natural resources, expanses of water, and ocean of air, it is necessary for man to begin storming space, a new and unstudied medium, which plays an important role in the life of man and all living things. But how necessary is man's participation in explorations and flights into space in manned space vehicles?

There is the opinion that unmanned spacecraft are the vanguard, the first scouts, which will be followed sooner or later by man. This is correct, but not entirely so. There is no doubt that investigations conducted on the surface or from the surface of other planets will be carried out primarily by automatic space laboratories, and the planets themselves will remain "not easily accessible regions" for us.

The possibility of productive human activity on other planets has not yet been adequately studied. The first test of this will be efforts to explore and develop the Moon. Even if all the conditions necessary for human life are present, it is unlikely that prolonged investigations on a planet's surface with direct human participation will be warranted for a long time.

The consideration of accidental danger awaiting man during space voyages is always introduced into discussions of this type. In addition, regardless of any improvement in the possibilities of spacecraft launched from Earth, there is a certain payload limit which a spacecraft can transport to interplanetary routes and orbits, even if principles such as assembly and docking are used. It is understandable that when such payloads include the weight of a crew and all its life-support systems, the scope of a scientific program is reduced since the number of research instruments used for this purpose is restricted.

What are the primary goals in the study of that region which is now called "deep space" and is being investigated by inhabitants of Earth with various spacecraft?

In a few words, they can be reduced to the following: reaching a fundamentally new level in our knowledge of the universe in general, and of regions surrounding our planet in particular.

The primary goals of space exploration include the investigation of the present state of the solar system in order to learn the principles of its origin and subsequent development. In this case, we are speaking primarily of a study of the chemical composition and physical properties of the atmospheres and surfaces of the planets and their satellites, the study of their interiors, more accurate determination of the masses and dimensions of bodies in the solar system, and investigation of solar corpuscular and electromagnetic radiation currents, magnetic fields, and cosmic dust in the solar system.

Exploration of regions of the solar system lying outside the plane of the ecliptic would be of great scientific interest. However, the launching of spacecraft into trajectories forming a large angle with the plane of the ecliptic will continue to be impossible for a long time because of power considerations. With a small angle of inclination a spacecraft can in principle move away to large distances from the plane of the ecliptic, but this would occur at a distance from the center of the solar system. And this means that regions of space "above" and "below" the Sun would remain inaccessible for some time.

Thus, we shall explore the solar system primarily in the plane of the ecliptic, where its main heavenly bodies, the planets, are to be found.

The large planets revolve around the Sun under the influence of the force of gravity in elliptical orbits, which are close in shape to circles and lie in a single plane, which is very close to the ecliptic, the plane in which the Earth revolves around the Sun.

The Sun is almost in the center of the planetary orbits. The reason for this is quite simple: 99.886 percent of the mass of the entire system is concentrated in the Sun so that its gravitational attraction completely determines the movement of the planets. All the small and large planets move about the Sun in the same direction, in a counter-clockwise direction as observed from the northern pole of the ecliptic. Most of the large planets, the Sun, and the Moon rotate on their axes in the same direction in which the planets move around the Sun. Venus and Uranus are exceptions.

The planets are insignificant in size in comparison with the enormous distances between them and the Sun. We shall merely recall that the distance from the Earth to the Sun, which comprises one astronomical unit, is approximately equal to 149.6 million kilometers. The order of the planets from the Sun is as follows: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune, and Pluto.

The distances of the planets form a regular sequence: the distance between successive orbits increases as their distance from the Sun increases. Gravitational interaction between the planets is insignificant. It causes only slight perturbations of their elliptical orbits.

As was mentioned above, the planets are divided into two groups, which differ in mass, chemical composition, rotation period, and number of satellites. The planets closest to the Sun (Mercury, Venus, Earth, and Mars) are called the terrestrial planets. One can also include the Earth's natural satellite, the Moon, in this group. Some astronomers also include Pluto in this group.

The planets of the terrestrial group are relatively small, have a similar chemical composition, and consist primarily of heavy elements with a high specific gravity. Thus, for example, the average density of Earth's matter is 5.5, where the density of water is taken to be one. A significant proportion of the mass of the planets of the second group, the major planets (Jupiter, Saturn, Uranus, and Neptune), consists of hydrogen and its compounds methane and ammonia. As the distance inward from the surface of these planets increases, the gaseous state gradually changes to a liquid condensed state at a depth of several hundred kilometers.

In recent decades planetary astronomy has been undergoing a period of rapid development. The use of new methods--radio astronomy, radar, and infrared spectroscopy--has made it possible to obtain a number of interesting and unexpected results and to become more familiar with our neighbors in the solar system.

Nevertheless, the most important role was played by the fact that heavenly bodies closest to the Earth became objects of explorations made using spacecraft. Flights of spacecraft have immeasurably increased our knowledge of interplanetary space and have forced us to make a basic reexamination of firmly established concepts of physical conditions existing on individual planets and, to a certain extent, have also stimulated the development of methods of observation used on Earth, which even today serve as an important source of information about physical conditions, atmospheric parameters, and surface features of the other planets of the solar system.

Thus, the Earth is only one of the planets of the solar system, which represents a relatively small group of heavenly bodies in one of the corners of the universe. In addition to the Sun, this system includes nine large planets with satellites, several tens of thousands of minor planets (asteroids). comets, and a large number of small meteoroids.

We wished to remind the reader of all this before passing on to our discussion of "tomorrow in space."

Naturally, it is difficult to predict all the scientific and engineering problems and questions that will become a reality in the near future. Only general statements can be made concerning the long-range goals of astronautics, including the exploration of the asteroids and the outer regions of the solar system. Without deceiving ourselves, let's dream a little...

* * *

Not only Mars, Venus, Mercury, and Jupiter but other planets and heavenly bodies as well have become objects of direct contact with envoys from Earth--spacecraft. Using automatic machines, we obtain unique scientific information from space. Venus, Mars, Mercury, and Jupiter are the special targets of space technology, toward which unmanned space probes continue to be launched. On distant flight routes and near these planets various scientific and technical experiments are being conducted. During prolonged flights spaceborne and land-based facilities for radio control and telemetry at large distances from Earth undergo comprehensive testing. The operation of scientific and service equipment is monitored. By analogy with the stages of the exploration of the Moon, a foundation is being laid for future, more complex space flights. Scientists and engineers are designing new unmanned spacecraft, which in a few years will replace those which are now exploring the universe.

Let us again note that unmanned spacecraft will play a leading role in this stage as they did in flights near the Earth and to the Moon, for they are much less expensive than manned spacecraft, are very reliable, and make it possible to obtain data from regions which are not easily accessible.

While unmanned spacecraft are being launched into deep space, structures and systems for manned spacecraft are being completed and flight conditions for astronauts are being studied. Unmanned space probes of various countries have enriched science with unique data concerning the physical parameters of Venus, Mars, Mercury, Jupiter, and the other planets. For the first time, science has obtained detailed photographs of the visible surfaces of these planets and a chemical analysis of rock samples from some of them as well. Extremely valuable material has been obtained for the development of the theory of the origin and evolution of the planets.

What are the most interesting space routes for unmanned spacecraft during this period?

We will discuss them and make several voyages with unmanned spacecraft to the vicinities of the planets of the solar system. It is no misfortune that these will be imaginary voyages; data from automatic machines will supplement our ideas and make them reliable to a certain extent.

Let us begin with voyages to the Sun and the planets Venus and Mercury. We already have quite a bit of information about Venus, the morning star, from the results of flights of unmanned spacecraft. It would be difficult for man to visit this planet, but unmanned spacecraft successfully solve this complex problem. Some of them land on its surface, and others "drift" in its atmosphere.

On this occasion we shall pass by Venus and fly directly toward Mercury.

Our interplanetary space vehicle should circle Mercury at a distance of 2,000-3,000 kilometers from its surface and then enter orbit as its artificial satellite in order to perform various experiments for a long period of time.

The spacecraft is equipped with a lander for landing on a planet's surface and an unmanned probe for a flight to the Sun. Let us imagine a landing on the surface of Mercury. In a way it is similar to Mars and the Moon. We see the remains of craters and detritus similar in appearance to disintegrated rock. Yes, volcanic activity, which in fact resulted in the formation of a mountainous relief, is possible on Mercury. Monitoring spectroscopic investigations show that there is no carbon dioxide here. It had been previously supposed that there were insignificant amounts.

However, we are not going to stay on Mercury for long: It is dangerous since much more solar radiation which is lethal for humans reaches its surface than reaches the Earth. Let us return to our spacecraft. While we rest after our voyage to Mercury, our unmanned probe continues its movement toward the Sun. The temperature is beginning to increase. The corpuscular and electromagnetic radiation currents from the Sun are becoming stronger.... We are receiving unique scientific data. It is unfortunate that contact with the spacecraft will end at a distance of 20-30 million kilometers from the Sun, but nothing can be done: this is the limit for the operation of instruments under such destructive conditions of high temperatures and radiation.

Besides the inner planets, much attention will also be devoted to explorations of the outer planets of the solar system, especially Mars and Jupiter. These planets have always attracted the attention of people on Earth, and it is not surprising that the trajectories of most unmanned missions are directed toward them. The exploration of Mars, for example, is being carried out by various countries according to a joint program, which is still another important demonstration of the advantage of multilateral international cooperation in the exploration and development of space.

Unmanned spacecraft have entered the orbits of artificial satellites of Mars and landed on various regions of its surface. The first Martian rovers have been transported to Mars and have given a large amount of valuable scientific information concerning our celestial neighbor, as was once the case with the first lunar rovers.

A completed complex of extensive investigations prepared the way for the first manned mission to Mars. It is supposed that this mission will be prepared by many countries, and its crew will consist of astronauts of various nationalities. All mankind impatiently awaits the flight of the first humans to this planet, which until recently was very mysterious for us.

But let us return to the missions of the automated space explorers to the most distant planets of the solar system: Saturn, Uranus, Neptune, and Pluto.

The program for these scientific experiments was worked out by scientists of many countries and was mutually agreed to. All mankind is closely following the flights of unmanned spacecraft to the distant outer planets.

Spacecraft setting out along these interplanetary trajectories are regularly equipped with probes, which can be launched to the surface of these planets. Upon approach to the planets, various experiments are performed: photographing, temperature measurements, investigation of radiation belts, magnetic fields, and many others. Asteroids, comets, and meteors are also studied...

* * *

In its travels through space mankind is making use of its best forces, mobilizing available resources, and depending on its best technological achievements. To this end, a systematic scientific search is being conducted in various areas of human activity. At times it is impossible to expect immediate direct practical results from the investigation of these new areas. This, however, does not stop scientists. The history of science has many examples of completely abstract doctrines and new physical phenomena the use of which would be difficult to imagine suddenly acquiring practical significance.

The process of penetration into space is taking place at a steadily increasing pace. Using several short examples, we have attempted to characterize astronautics in the future. It would have been possible to cite a rather large number of other space projects having various problems, objectives, and possibilities that are being discussed by specialists. However, the authors had a different purpose: to show that man has entered space not through idle curiosity but to master and make use of its limitless expanse. And this process is truly beginning to bring him "mountains of bread and an abyss of power"!

K.E. TSIOLKOVSKIY'S PLAN AND ITS REALIZATION

Even today we are disturbed by K. E. Tsiolkovskiy's Plan," which was described in his work "Issledovaniye mirovykh prostranstv reaktivnymi priborami" [The exploration of outer space using rocket devices] in the beginning of the twentieth century.

Let us recall his basic stages:

1. A jet plane with wings and ordinary controls is built. The objective is to learn to fly an aircraft with a rocket engine, regulate thrust, and soar with the engine shut off.

2. Wings of subsequent aircraft gradually become smaller, while thrust and speed increase.

3. Penetration into very rarified layers of the atmosphere.

4. Flight beyond the atmosphere and gliding descent.

5. Establishment of mobile stations outside the atmosphere (artificial Earth satellites).

6. Use by astronauts of solar energy for respiration, eating, and other everyday needs.

7. Space suits are made, for safe exit from a rocket into space.

8. Large settlements are established around the Earth.

9. Solar energy is used not only for eating and living conveniences (comfort) but also for locomotion within the entire solar system.

10. Colonies are founded in the asteroid belt and other places in the solar system where only small heavenly bodies are found.

11. Industry in space develops. The number of space stations multiplies.

12. Individual (personal) and social (socialist) perfection is achieved.

13. The population of the solar system becomes 100,000 million times greater than that on Earth at present. A limit is reached, after which repopulation of the entire Milky Way is inevitable.

14. The Sun begins to grow dim. The remaining population of the solar system leaves it and goes to other Suns to join their brothers who had left earlier.

Already today, two-thirds of the points of this brilliant plan for the future have been fulfilled. This is already history, the history of work and victories! But even now one experiences deep anxiety and pride when one reads the ideas of a scientist which were made more than half a century ago. What insight! What scope! Yes, such a plan is a basic program for the distant future; it is a problem having vast importance for the life of mankind! Such ideas inspire, find thousands of adherents and followers. Such a plan cannot die, for it is immortal.

What we have discussed in this chapter is essentially "K. E. Tsiolkovskiy's Plan" for the next decades presented from today's point of view by scientists of various countries. The ideas are essentially the same, and it could not be otherwise, for Tsiolkovskiy was truly ahead of his time and remarkably accurately anticipated the basic stages in the development of rocket technology and astronautics, correctly formulated the goals and problems, and sketched the appearance of future rocket spacecraft.

In accordance with this "Plan..." we shall now construct a table of proposed developments (even those that may seem fantastic today) in astronautics and associated problems, which we have provisionally called "Pictures of the Future."

The table has been based on domestic and foreign publications. The lines indicate ranges of possible dates for the realization of a given project according to estimates of various scientists.

Let the training and work of our contemporaries and of future generations bring the dates for the solution of these complex problems closer. Let these dates become for us not only a guide but a reality--a symbol of man's victories in his struggle with the forces of nature.

People living at the beginning of the next millenium will surely examine this table under a new heading, for, having crossed out the fantastic title "Pictures of the Future," they will put in a new inscription:

"Fulfilled. Accurate with the correction: Past." Well, this too is remarkable since it will mean that our dreams have not only been realized but multiplied!

Table 8.2. "Pictures of the Future" Predicted Today

Development

Astronautics:

Reusable launch vehicles

Photon rocket

Nuclear engine with solid core

Nuclear engine with gas-phase reactor

Electromagnetic and plasma engines (continuous operation)

Orbiting space station, crew above three

Orbiting science space station with crew of 10 or more

Reaching areas of solar system 5-6 billion kilometers from Earth (region of Pluto)

Effective rescue system for astronauts involved in accidents

Temporary lunar base (2 men, 1 month)

Organization of permanent scientific research base on Moon (10 men for prolonged period)

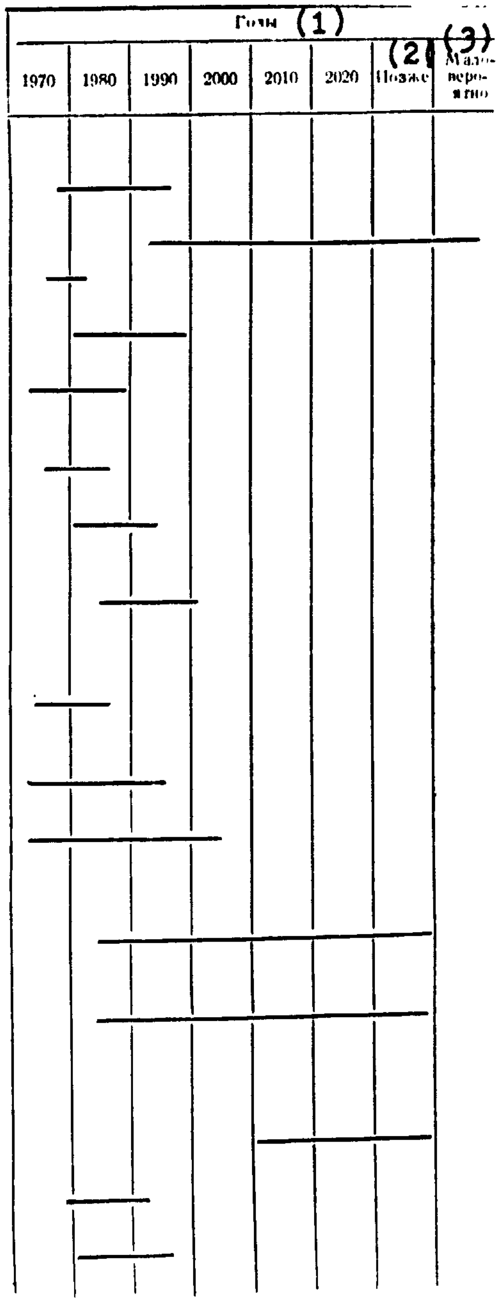
Production of rocket fuel from lunar raw materials

Use of planetary raw materials for life support and feeding of vehicle and station crews

First human born away from Earth

Return of Martian soil and Martian rover vehicles

Landing of man on Mars



[Table continued on following page]

	Годы (1)							
	1970	1980	1990	2000	2010	2020	(2) Позже	(3) Маловероятно
Temporary base on Mars (2 men, 1 month)			—	—				
Manned flyby of Venus	—	—	—					
Landing of men on Venus				—	—	—	—	
Permanent scientific research stations on nearest planets	—	—	—	—				
Landing of men on Jupiter's satellites			—	—	—	—	—	
Manned flyby of Pluto					—	—	—	
Launch of unmanned probes beyond solar system		—	—	—	—			
Manned flight to star systems lasting several generations					—	—	—	—
Laboratories and observatories outside solar system					—	—	—	
Exchange of information with advanced extraterrestrial civilizations				—	—	—	—	—
Cargo and passenger ballistic transport	—	—	—					
Scheduled cargo and passenger transport with lunar station		—	—	—	—			
Anti-radiation devices		—	—		—	—	—	—
Certain Scientific and Technological Problems Associated With the Development of Astronautics:								
A. Food								
Equipment for long-term food storage, preventing spoilage during storage	—	—	—					
Laboratory produced photosynthesis		—	—	—				

[Table continued on following page]

	Годы (1)							
	1970	1980	1990	2000	2010	2020	Позже (2)	Маловероятно (3)
Production of synthetic food products from petroleum, gas, coal, etc.	—	—	—	—				
B. Physics Problems								
Experiments with antiparticles, which should lead to the creation of antimatter elements at antiatomic and antimolecular levels		—						
Controlled thermonuclear reactions		—	—	—				
Efficient electrical energy storage systems	—	—	—					
Miniaturization of electronic devices to the molecular level				—	—	—	—	
Building of operational nuclear powerplants with capacity of 3-4 million kW		—	—	—				
Unified, up-to-date theory of elementary particles	—	—	—					
C. Production, Storage, and Transmission of Power								
Polymer superconductor storage cells	—	—						
Extensive use of fuel cells	—	—						
D. Long-Range Weather Forecasting and Control	—	—	—	—	—	—	—	
E. Biology, Genetics, Medicine, and Psychology								
Automatic diagnosis of diseases	—	—	—					
Determining the nature of and finding methods of treating malignancies		—	—					
Preparations which make it possible to prolong human life			—	—	—	—	—	—

[Table continued on following page]

Control of heredity

Overcoming tissue incompatibility

Use of suspended animation for prolonged space flights

Direct recording of knowledge in human brain

"Artificial life"

Increasing human life span by more than 2-3 times

Memory control; restoration of information previously fixed in brain

F. Computer Technology and Control

Creation of program languages suitable for information exchange

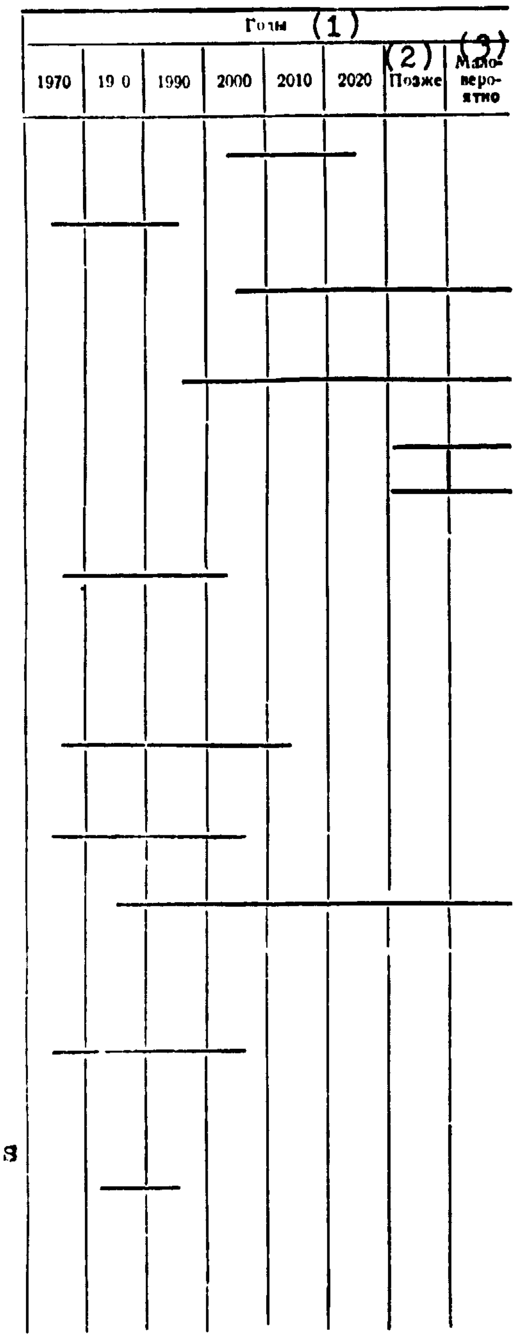
Production of machine storage with billions of memory cells

Symbiosis of man and computer using electrical signals emitted by brain

G. Materials Science

Production of ultrastrong, light, inexpensive materials for spacecraft housings designed to withstand pressures of more than 1000 atmospheres

Extensive use of single crystals of metals and compounds for ultrastrong structures



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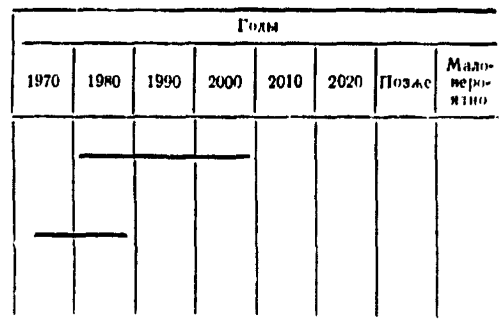

Production of superconductors which operate at temperatures ± 100°C

Development of synthetic materials for superlight structures

Key:

1. Years
2. Later
3. Unlikely

BIBLIOGRAPHY

1. Astashenkov, P. T. "Akademik S. P. Korolev" [Academician S. P. Korolev], Moscow, Mashinostroyeniye, 1969, 207 p.

2. Borisenko, I. G. "V otkrytom kosmose" [In open space], Moscow, Mashinostroyeniye, 1974, 157 p.

3. Bestuzhev-Lada, I. V. "Okno v budushcheye" [A window into the future], Moscow, Mysl', 1970, 269 p.

4. Vasil'yev, M. V. "Vekhi kosmicheskoy ery" [Landmarks of the space age], Moscow, Mashinostroyeniye, 1967, 225 p.

5. Varvarov, N. A. "Sed'moy kontinent" [The seventh continent], Moscow, Moskovskiy rabochiy, 1973, 287p.

6. Vereshchetin, V. S. "Kosmos, sotrudn'·hestvo, pravo" [Space, cooperation, and the law], Mo. ow, Nauka, 1974, 165 p.

7. "Vperedi svoyego veka" [Ahead of his/its time], Moscow, Mashinostroyeniye, 1970, 310 p.

8. Glushko, V. P. "Razvitiye raketostroyeniye i kosmonavtiki v SSSR" [The development of rocket building and astronautics in the USSR], Moscow, Izd. APN, 1973, 56 p.

9. Gurshteyn, A. A. "Izvechnyye tayny neba" [Age-long secrets of the heavens], Moscow, Prosveshcheniye, 1973, 255 p.

10. Denisov, N. N. "Na beregu Vselennoy" [At the edge of the universe], Moscow, Mashinostroyeniye, 1970, 383 p.

11. Denisov, V. P., and Alimov, V. I. "Luna i planety" [The Moon and the planets], Moscow, Znaniye, 1971, 32 p.

12. Denisov, V. P., and Alimov, V. I. "Pyatnadtsat' let kosmicheskoy ery" [Fifteen years of the space age], Moscow, Znaniye, 1972, 63 p.

13. Dmitriyev, A. Yu. et al. "Ot kosmicheskikh korabley k orbital'nym stantsiyam" [From space vehicles to orbiting stations], Moscow, Mashinostroyeniye, 1971, 114 p.

14. "Zondy issleduyut lunnuyu trassu" [Probes explore the lunar route], Moscow, Mashinostroyeniye, 1969, 31 p.

15. Ivanov, A. "Pervyye stupeni" [The first steps], Moscow, Molodaya gvardiya, 1970, 174 p.

16. "Inzhenernyy spravochnik po kosmicheskoy tekhnike" [Engineer's handbook of space technology], Moscow, Voyenizdat, 1969, 693 p.

17. "The Space Age. Predictions for the Year 2001" (translated from the English), Moscow, Mir, 1970, 420 p.

18. "Kosmicheskiy marafon" [The space marathon], special issue, Moscow, Izvestiya, 1970, 237 p.

19. "Astronautics" in "Malenkaya entsyklopediya," Moscow, Sovetskaya Entsyklopediya, 1970, 591 p.

20. "Kosmos cheloveku" [Space for man], Moscow, Mashinostroyeniye, 1971, 211 p.

21. "Luna-16. Kosmicheskiy geolog" [Luna-16. Space geologist], special issue, Moscow, Izvestiya, 1970, 189 p.

22. Martynov, D. Ya. "Planety. Reshennyye i nereshennyye problemy" [The planets. Solved and unsolved problems], Moscow, Nauka, 1970, 439 p.

23. "Mezhplanetnyy reportazh Venera-Zemlya" [Interplanetary reporting between Venus and Earth], special issue, Moscow, Izvestiya, 1969, 190 p.

24. "Most v kosmos" [A bridge to space], Moscow, Izvestiya, 1971, 623 p.

25. "Naukovedeniye, prognozirovaniye, informatika" [The nature of science, forecasting, and information science], Kiev, Naukova dumka, 1970, 349 p.

26. "Oktyabr' i nauchnyy progress" [The October Revolution and scientific progress], Moscow, izd. APN, 1967; Vol 1, 629 p; Vol 2, 615 p.

27. "Pervoye puteshestviye lunokhoda" [The first voyage of the lunar roving vehicle], special issue, Moscow, Izvestiya, 1970, 127 p.

28. Petrov, B. N. "Kosmicheskiye issledovaniya i nauchno-tekhnichiskiy progress" [Space exploration and scientific and technical progress], Moscow, Znaniye, 1971, 46 p.

29. "Pokoreniye kosmosa" [The conquest of space], Moscow, Mashinostroyeniye, 1972, 179 p.

30. Ponomarev, A. N. "Gody kosmicheskoy ery" [The years of the space age], Moscow, Voyenizdat, 1974, 291 p.

31. Popovich, P. R. "Vyletayu utrom" [I fly off in the morning], Moscow, izd. DOSAAF, 1974, 181 p.

32. "Put' v kosmos" [The road to space], Moscow, Pravda, 1958, 319 p.

33. "Salyut na orbite" [Salyut in orbit], Moscow, Mashinostroyeniye, 1973, 160 p.

34. Titov, G. S. "Golubaya moya planeta" [My sky-blue planet], Moscow, Voyenizdat, 1974, 291 p.

35. "Uspekhi SSSR v issledovanii kosmicheskogo prostranstva" [Successes of the USSR in space exploration], Moscow, Nauka, 1968, 556 p.

36. Ursul, A. D. "Osvoyeniye kosmosa" [The mastery of space], Moscow, Mysl', 1967, 237 p.

37. "Tsiolkovskiy K. E. v vospominaniyakh sovremennikov" [Tsiolkovskiy K. E. in the recollections of his contemporaries], Tula, Priokskoye izdatel'stvo, 1971, 335 p.

38. Shklovskiy, I. S. "Vselennaya, zhizn', razum" [The universe, life, and reason], Moscow, Nauka, 1965, 283 p.

39. "Estafeta Kosmicheskikh startov" [A relay race of space launches], special issue, Moscow, Izvestiya, 1974, 165 p.

40. Yanch, Erikh. "Prognozirovaniye nauchno-tekhnicheskogo progressa" [Prediction of scientific and technical progress], Moscow, Progress, 1970, 567 p.